APPL

Spotlight

This month, a look at KSC's Checkout and Launch Control System team

Spotlight: CLCS Team

Why Study NASA Project Teams?

You can draw a straight line from successful project team development to successful project performance. NASA approaches all of its major missions by forming project teams. The way these teams develop is often more intuitive than conscious. Project managers rarely think of team development as a process separate from project performance, and the team members themselves are usually unaware of how their team was formed. Although PMs do recognize the team's importance to a project's success, they often fall back on statements such as "the chemistry was just right" when asked specifically about how the team developed. By looking more carefully at the practices and experiences of project teams across NASA, we can learn what's worked and what hasn't. This kind of analysis can turn team development from an intuitive process into a concrete and conscious one.

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Why Study NASA Project Teams?
High Performing Project Teams

In 1998 and 1999, eleven NASA projects participated in a NASA study of project team development and performance which led to a clear understanding of the characteristics of high-performing project teams. These common characteristics include:

- a strong **team focus** that lets members look beyond their own individual wants to see what the team needs to succeed;
- rapid, open, and frequent **communication** from top to bottom that gives team members the information they need to do their jobs, even if this information is preliminary;
- **empowerment**, so that members can influence everything that goes on in the project;
- influence based on **competence**, and not on favoritism or organizational politics; this includes the knowledge and skills needed to perform technical tasks, the willingness to perform, and the ability to fit one's own competence into the larger needs of the project;
- a **diversity** of skills and experience levels among team members and a willingness to accept and use these differences as powerful assets for identifying and solving problems;
- a project **structure** which defines clear roles and responsibilities without leading to rigidity: members know how their own jobs are connected to those of their fellow team members, and they understand the process of making changes that affect the schedule, requirements, or interfaces;
- an understanding among team members of the **interdependence** between their individual competencies and those of others; they make full use of each other's skills and expertise, they cooperate, and they trust the information provided by those on the team;
- a demonstration of high levels of **commitment** among team members, working on problems until they've been solved, refusing to fail, and often making personal sacrifices of time and effort;
- a demonstration by members of strong loyalty to the team: they include each other in decisions, and respect each other's contributions--qualities which give the team great **cohesion**;
- the assumption of responsibility by the project for **recognition** of its own successes, as well as the contributions of individuals and teams within the project; with portions of meetings used to draw attention to achievements.

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Why Study NASA Project Teams?
Measuring Teams

A powerful strategy for improving team development in any project is incorporating team development assessment into the regular process of performance assessment. TeamMates, NASA's tool for project team development assessment, offers a formal metrics-based process for this kind of assessment. It measures how project team members perceive the development of the ten project team characteristics known to strongly correlate with successful project performance.

CLCS participated in the NASA study that led to the development of TeamMates (findings from the NASA Project Team Development and Performance Study are online). Results of the team development assessment identified overall strengths and opportunities for improving team development within CLCS. The assessment results also provided the CLCS management team with similar information regarding the project's sub-groups.

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The Checkout & Launch Control System (CLCS) was formed in the wake of a costly and unsuccessful attempt to design a replacement for the existing Launch Processing System (LPS), which dates from the 1970s [See history of the LPS shuttle]. The project is the direct result of recommendations from a 60-day "proof of concept" team that was formed in 1996. The goal of CLCS is to design and implement a replacement for the existing LPS, using state-of-the-art commercial equipment and software. The system that CLCS is developing is aimed at making shuttle operations faster, cheaper, and safer.

The complexity of designing, developing, and deploying a vast system of hardware and software that needs to interface with existing ground-support equipment and orbiters requires a large and technically diverse project. This complex structure presents its own management challenges, namely how to maintain focus, communication, and cohesion across many teams and organizational boundaries (for example NASA vs. contractor). Furthermore, integrating the system's many components also poses many technical challenges.

Features of the new system include:

- a graphical user interface;
- separate command and data monitor paths;
- the ability to perform tests across multiple disciplines;
- the simultaneous control of multiple orbiters at different stages of testing and checkout;
- the ability to perform tests across multiple systems or components.

These features are expected to:

- reduce the operations and maintenance costs;
- provide building blocks to support future hardware and software elements that cannot currently be supported;
- significantly reduce processing times for shuttle fights.

In brief, CLCS will lead to more flights, safer processing, and lower costs. CLCS is being designed by a team of engineers and programmers from NASA, Lockheed Martin, United Space Alliance (USA), and Dynacs. The final product will include a core system and applications. The development process adopted by CLCS is based on incremental releases of specific sets of individual components. This incremental design and release strategy accomplishes the following goals:

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- it allows for continued input from the end-users (the shuttle operations-groups);
- it supports the modular nature of the overall system;
- it is expected to help the project remain on schedule and within budget.

How is CLCS Organized?

CLCS is a large, technically complex, dispersed, and multi-organizational project.

CLCS Organization

Project Manager	**Deputy Project Manager**
Bruce Hevey	Ric Hurt

Product Groups

Application Software	**Real-Time Systems**	**Support Systems**	**Gateways**
Ben Bryant	Mike Dotterweich	Larry Carr	Shawn Quinn
NASA	Lockheed Martin	USA	NASA

Integration Groups

Systems Engineering and Integration Team		**Project Controls Office**
Wayne Prince	John Straiton	Mike Bolger
NASA	USA	NASA

User Liaison NASA	**User Liaison USA**
Jeff Wheeler	Chris Best

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Best Practices

What Make CLCS a Good Team?

It was clear from interviews taken during CLCS's participation in the NASA Project Team Development and Performance Study that the CLCS management team understands how ultimate project success is predicated on strong teams. The interviews also showed how members of the management team, as well as leaders of the sub-project groups, make significant efforts to model good team behavior. Some examples are listed below:

- Early efforts were made in the project to build **team cohesion** by including all team members--across organizational boundaries--in communications processes and celebrations, and by assigning leadership roles to both NASA and contractor employees. These efforts are intended to create as much of a "badgeless" culture as possible.
- **Communication** across the large CLCS structure (more than 4500 team members) is a constant focus of attention, making use of e-mail, a project web site, and weekly update meetings. As PM Bruce Hevey puts it, "Communication is absolutely key. It's the people, processes, common sense, but, above all, communication."
- Teams are challenged and **empowered** to solve unforeseen problems, and interdependence is fostered through the shifting of personnel and budgetary resources across teams to accomplish the project's overall objectives.
- The achievement of **major milestones is recognized** within the project, and the project continues to reward its members' contributions (for example, by granting them special access to the control room, or by having them participate in discussions with astronauts).

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Regular assessment can point out problems that need to be solved. CLCS underwent a series of independent assessments in 2000, the results of which pointed out several shortcomings. Each of these problems was addressed by the CLCS team members. Below is a list of specific problems and how they were tackled.

- **Schedule pressures often led to shortcuts:** CLCS now enforces stronger measures to verify the completeness of processes.
- **SEIT did not cover applications software:** SEIT (System Engineering and Integration Team) and software developers now draw up criteria for each design phase, and SEIT determines when these criteria have been met. This process improves the consistency and quality of application products.
- **A lack of accountability among contractors:** Roles and responsibilities have been clarified or redefined. All real-time system software responsibility has been shifted to Lockheed Martin, while responsibility for support systems and software has been assigned to United Space Alliance (USA).
- **Miscommunication and duplication of efforts:** CLCS sharpened the focus of meetings to provide a better forum for handling issues. In addition, after a reorganization driven by independent assessments, the Work Breakdown Structure was modified to clarify roles and responsibilities further.
- **Progress is difficult to measure:** To provide better verification of progress and process completion, the PM created a new Performance Measurement Team with representatives from each group. They were responsible for coming up with a consistent set of metrics that all product groups could use to measure their progress. The team was successful, and devised a consistent set of metrics that is now in use throughout the project.
- **A team falls behind schedule:** The project took advantage of interdependence and team focus to help one of the software teams. For a certain group of CSCIs (specific Computer Software Configurable Items), a software unit ran into unforeseen problems and reported that it wouldn't meet its internal project schedule. Yet three other units were projected to finish early, so personnel and budgetary resources were shifted from these three units to the one in need. Team focus meant that people cooperated, taking on new tasks in order to help. This process was only possible because of the metrics that were devised to assess progress across all the product groups effectively, and because the PM fostered a climate that ensures teams speak up when they run into trouble.

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- **Software inconsistency:** One of the COTS (Commercial Off-The-Shelf) tools used to design CLCS has powerful visual development capabilities. A team within the Application Software Group that was using this tool (two years, and millions of dollars, into the project) started seeing applications that were too large to run the designed hardware configuration. A trouble-shooting team within the Application Software Group used the CLCS issue-tracking database to identify everyone reporting similar problems, analyzed the results, and proposed a solution. It turns out that some teams were deviating from the overall design feature of keeping code similar across different components. The solution was to institute peer inspections at the design level, and not only at the software code level. The entire applications software group was made responsible for integrating actions across the whole application set.

  The Application Software Group now identifies common areas of programming, and its members are sharing information about what works and what doesn't. This fits in well with the overall CLCS goal of reusing software blocks, and also helps CLCS to meet its goal of reducing maintenance costs: users can now move across the system while working on different components, because the underlying design of the code remains the same.

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Below are some practical management techniques based on the experience of the CLCS project management team:

Team Management Practices

- **Hand-pick your team:** To ensure a highly committed and competent team, CLCS group leaders worked hard to convince managers outside of (and above) CLCS to hand-pick many of the team members. Identify the key players, and foster teamwork across organizational boundaries. Don't load up a team with only "A-team" folks. To maximize productivity, mix the experience levels by including individuals with a range of experience ranging from extensive to minimal. Your most experienced people will butt heads if there are too many of them on one team. Having new members aboard gives them the experience they can use for future NASA projects.
- **Don't play favorites:** Strive for a 'badgeless culture.' Everyone has to be considered part of the team and respected as a valuable contributor, whether a NASA person or a contractor. With two or three different contractors working on the same project, you have a significant challenge. Contractors have tight corporate relationships, and this sometimes means that they're competing for future business, yet they still have to work together on the same team.
- **Avoid scheduling milestones that overlap:** You don't want to complete the engineering and integration activities for one system at the same time that you're designing and planning for another; you'll need your most experienced and competent people to work out last-minute problems. To keep things on track, you need the same people available at the planning stage of the next delivery. Trying to do both things at once overloads your best people, and puts the project at risk. As CLCS Product Leader Mike Bolger puts it, "You've got to have hard milestones, but you've also got to manage those milestones. You've got to set expectations and make sure your team knows what those expectations are."
- **Plan for the unexpected:** Unforeseen problems will occur. Deal with them by building contingency time into the schedule. Identify problems as early on as possible--which means you'll need accurate assessments of progress and open communication. Once problems have been identified, make full use of team focus and the team members' commitment by allowing them to help other teams when problems crop up.

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- **You can never communicate too much:** To foster communication, make use of both formal and informal processes. Hold weekly update meetings for the product groups and integration teams (with an agreed-upon time limit; for example, one hour). Address questions such as “Is the team going to meet this week’s objectives?” or “What issues are threatening the schedule or budget?” In addition, make informal rounds to check in with team members personally. Give the appropriate people the chance to contribute to formal and informal updates, and encourage people to speak up (formally or informally) if they’re aware of a problem. People at Kennedy still remember the Challenger tragedy--and the cost of not communicating problems.
- **Care for your team members as people:** Take time to relax and unwind. In project management, you often fall behind on a particular schedule, and then there’s intense pressure to catch up. A good manager has to know when he’s pushed his people as hard as he can push them; sometimes the staff has to be given some time off.
- **Practice good coaching skills:** When interpersonal problems arise in teams, don’t dictate solutions. Instead, identify the problem and allow the individuals to come up with solutions themselves.

General Project Management Practices

- **Remember the customer:** Get your end-user community involved early on, and keep them involved during the design, development, and deployment phases. No matter how good a job your developers think they’ve done, the product isn’t a success unless your customer says it is. In light of an earlier failed attempt at replacing the LPS, for example, CLCS made a very conscious effort to involve the customer. A User Liaison Team headed by Jeff Wheeler was created to establish and maintain a high degree of customer involvement in the overall design, and to gain the customer’s acceptance well before the actual operational deployment (projected for 2005). As Wheeler says, “By having the users involved early in the process, we’ve given ourselves the best opportunity for success.”
- **Buy COTS (Commercial Off-The-Shelf):** To meet the overall goal of reducing the maintenance and processing costs for the shuttle, CLCS depends largely on COTS hardware and software (up to 85% and 50%, respectively). The challenge of using this much COTS has been in knowing where the application needs are at the fringe of the manufacturer’s products, and then

carefully deciding when to opt for a custom-designed product (e.g., where time is an issue). As Deputy Project Manager Ric Hurt puts it, “If you’re working at a bank, you want the computers to get the numbers right, but if they’re a bit slow it’s not a catastrophe.” On a flight mission, however, if data is transmitted too slowly or out of synch, the risks of potential danger increase.

- **Network:** Because the members of the team are highly experienced and skilled engineers, they’re respected both within and outside of NASA. They can (and are expected to) draw upon professional contacts for advice and possible solutions. For example, CLCS is using the experiences of others in the field, in this case the US Air Force, to find solutions to console glare. The team members are relying upon professionals within the US Air Force who have dealt with this problem already.
- **Identify the fringes of technology:** Whenever you’re working at the fringes of technology, you’ll encounter bigger risks. Use custom-designed products for these high-risk applications. Vendors will bend over backwards to sell you things for all kinds of uses--including at the fringes--but they won’t be willing to maintain the item as the market develops in other areas.

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We can see the results of CLCS's team focus reflected in how this project has performed. The release of Titan, the most recent CLCS milestone, appears to be on track. Internal testing has shown a high overall level of quality, and early feedback from application developers has been positive. A major wave of testing, with a high degree of customer involvement, was scheduled for August 2001. The users at the Hypergolic Maintenance Facility (HMF) are in the process of testing their final application software, and have reported very favorable reactions to the overall CLCS capabilities. Though CLCS certainly faced significant challenges, the team's efforts overcame them.

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PM Spotlight

CLCS Project Manager Bruce Hevey

When we asked Bruce Hevey to explain some of the key ingredients of project management, he pointed out the importance of communication (as much as 90% of the job) and common sense (the other 10%). As Hevey sees it, today's successful project manager has to go into battle with three skills. The first: the ability to put together a good team of trusted and skilled managers, backed up by a motivated workforce. The second: the ability to demonstrate, repeatedly and effectively, how to stick to the plan. The third: flexibility and adaptability in responding to problems.

This may look like common sense on paper, but what does it look like in practice? Hevey, a retired Air Force program manager and tanker pilot, has some suggestions based on his personal experience.

1) **No surprises:** "Something that I learned from one of my previous bosses is that I can accept technical problems, and I can accept schedules being behind, but what I have a hard time accepting are surprises. Surprises can be as big as when something's due on June 1st and someone walks in on May 15th saying he's going to be three months late--or even two months late--and that's the first I hear of it. That's not going to fly. As soon as people know that they're falling behind, management needs to know about it, so that they can make the appropriate trade-off among resources in order to mitigate the problem. That's what our job is: to get help for people, and we don't do that unless they tell us that they're falling behind. It's all part of communication; it has to be that constant flow of communication -- understanding where you are as early on in the process as possible, so that you can manage your way out of the box."
2) **Expect the unexpected:** "You're going to find jobs that have problems. It's probably more common to be behind schedule than exactly on schedule. But the crucial thing is knowing where you stand in terms of your plan: being able to assess your progress using earned value measurements and other methods. One of the key things is to develop metrics, but not just for the sake of telling your boss, 'I've got metrics.' Develop metrics that really help you do the job. That's what they're made for."
3) **Find a few people you can trust, and build from there:** "Because I've moved a lot and changed jobs a lot, my time in the Air Force prepared me for coming into an environment where I didn't know anybody. In a case like

this, I quickly try to find a few people I can rely on, people I call "trusted agents". These are people who you lean on heavily in the early days to get you up to speed with the organization, the work, and the key issues. By talking to--and more important, carefully listening to--people when you first land in a new organization, you can get a gut feeling on who you can rely on for counsel and advice--people who are going to give it to you straight and who aren't trying to sugarcoat things. You rely on those folks initially, and it grows from there."

4) **Know your role as a leader, and not a techno wizard:** "I'm not a technical guy. Yes, I have an engineering degree--you can't get a job down here unless you have an engineering degree--but it's not what I rely on, day to day, to do my job. When these guys get into deep technical discussions in a meeting, I either get them back on the subject at hand, or leave because I'm not in the right meeting!

"My role is to be a leader and manager. And management here means social engineering more than anything else: making sure you've got the right engineers talking to the right engineers, and the right users talking to the right designers and developers, so that we're going to give them a product they'll be happy with in the end. I'll never have to sit down and draw a schematic diagram, or design a gateway. It's just not in my job jar. And I don't pretend that I want to do that. I've got very smart engineers who work for me, and I know enough to let them do their job and not tell them how to do it."

"My job is to provide the strategic vision for the team, keep them communicating, and monitor their progress towards our goals. With that said, it's really interesting how some of our biggest challenges on a day-to-day basis continue to involve effective communications within the project and with our customers. We've got 500-600 people out here working hard every day trying to do the right thing… the challenge is making sure they're all working with the same focus and target."

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Larry Carr of United Space Alliance (USA) heads up a team of 200 people. USA is NASA's Space Flight Operations Contractor, which means that they're the "caretakers" of the shuttles, beyond their actual maintenance. At $4 billion per shuttle, this is no mean task. What's unusual about the USA-NASA relationship is that USA, in a sense, is the customer, while NASA is the contractor. This role reversal creates a unique opportunity for NASA officials to experience a project from the customer's perspective. In the case of CLCS, it is USA which decides whether or not the stages of a particular project are operational or not, and this determination is based first and foremost on safety. "USA has a complete risk-management training," Carr says. "A system that involves risk analysis, score-cards, and metrics. NASA has used this system as well."

Carr sees himself as more of a team leader than a director. He favors a management style where responsibility is assumed at all levels. A project is broken down into subgroups and micro-teams, each with a distinct product or goal. With everyone assuming a degree of responsibility, each person has ownership of the product. If all the parties are interested stakeholders as well, this encourages a kind of "virtual profit-sharing." To keep an eye on the big picture, products are integrated at weekly or monthly meetings, where Carr delegates responsibility to the team. He manages the process of integration, while allowing the teams to handle the actual product details. Basically, he sees himself as a project manager and a program manager at the same time, and constantly adapts in order to balance the two jobs.

Carr fosters teamwork by looking at jobs from all levels: the small picture (teams), medium picture (integration level), and the big picture (project level, shared across all the teams). The difficulty in this, he says, is identifying all the stakeholders--which in the case of CLCS amounts roughly to an equal share among NASA, Lockheed, and USA. It's sometimes hard for Carr to see beyond his part of the project (i.e., NASA's 200 people) and remember the larger issues at hand.

Most project managers value the luxury of handpicking their team members. Carr was in the fortunate situation of being able to pick those who actually reported to him, while they in turn could choose the next level, a system Carr refers to as "tiered support." This tiered structure is central to the efficient oper-

ation of CLCS, as it allows for smooth communication at and across all levels. Carr is also a rare proponent of meetings, believing that these oft-dreaded bureaucratic encounters can prove productive and enriching as long as there's a clear agenda, and only the relevant people are on hand.

The main problems in his group have involved dealing with the growth and scope of the project. The initial budget was for five years, and now five more years have been added, with the attendant increase in funding. The team has been coping with these challenges by using good metrics, which let Carr know in advance if things are going to be delayed. But, Carr adds, what's more important than simply having this valuable resource is actively reading and responding to the data that it provides: recording reams of facts and figures is useless if they're not put to good use. And, so far, the initial metrics have indicated that the customer is very satisfied with the CLCS project.

Another key player involved with CLCS is Mark Dotterweich of Lockheed Martin. His company provides the real-time software for CLCS. Like Carr, he also heads up a team of 200 people. He agrees with Carr that the CLCS customers (in this case, NASA and USA) have been satisfied thus far: Feedback on the latest delivery package, known as Titan, has been positive--users report satisfaction with the enhanced automation and user-friendliness--and Scout is due soon.

Dotterweich finds the incremental rollout of CLCS to be pivotal to its success. Rather than unveiling a finished project in one fell swoop, CLCS has been following the new NASA policy of a staggered rollout, in this case releasing useable segments of the project every six months. Yet even with this convenient and manageable timeline in place, Dotterweich still finds scheduling and system integration to be the biggest problems. Though most of his activities now involve resolving thorny issues of planning and resources, he used to be on the technical side of things, which may account for his penchant for statistics: like Carr, he feels that metrics are the most important key to managing vast projects like CLCS. His closing advice to PMs: "You can never plan too much."